Physics Division Overview

Jim Siegrist

Director's Annual Review

November 8-9, 2005

A Center of Excellence for the HEP Community

- *Physics Ideas from LBNL*
  - Asymmetric B Factory to probe CP violation in quark sector
  - Supernovae to measure the acceleration of the Universe
- *Innovation at LBNL*
  - Time Projection Chamber (TPC)
  - ASICs for silicon vertex detectors and pixel detectors
  - CCDs for space and ground-based astronomy
  - Analog Transient Waveform Digtiizer for non-Accelerator experiments
- *Instrumentation developed at LBNL*
  - BaBar: Silicon Vertex Tracker, Cerenkov Ring Detector, Trigger
  - CDF: Central Outer Tracker, Run II silicon
  - ATLAS: silicon strip modules and pixel detectors

Creativity, Ingenuity & Technical Capability

Infrastructure is Highly Leveraged

- Outstanding faculty supported by UC Berkeley
- Small but dedicated full-time scientific staff
- Excellent technical resources
  - Computing Division (NERSC)
  - Engineering Division (e.g. IC design)
  - Large machine shops, clean room facilities
- Direct support from the lab via LDRD
- Synergy with Nuclear Science and Accelerator Divisions

LBNL Contributions Enhance University Collaborations

- **LBNL collaborates closely with the University community:**
  - ✓ **Shared equipment and infrastructure for chip design, silicon detector systems**
  - ✓ **Engineering expertise in advanced electronics, instrumentation and mechanical design**
  - ✓ **Integration of theory with experiment**
  - ✓ **Computing expertise and operations support from NERSC**

Program Overview

- **Accelerator Experiments**
  - Present: BaBar, CDF
  - Imminent: ATLAS
  - R&D: ILC
- **Non-Accelerator Experiments**
  - Present: KamLAND, SCP/SNF
  - R&D: SNAP, APEX-SZ, South Pole Telescope
  - Incubating: θ_{13} at a reactor, CMB polarization
- **Community Service**
  - PDG, Quarknet, Leadership

SNAP (Dark Energy) and ATLAS (EWSB) are our highest priorities

In this review

- You will see how
  - New theoretical ideas from LBNL challenge current and future experiments
  - Current experiments at the Tevatron and later ATLAS at the LHC will probe the energy frontier and the limits of the standard model
  - Our programs in supernova cosmology and the cosmic microwave background are exploring the 95% of the universe that lies beyond the standard model
  - A reactor-based experiment can initiate the next phase of neutrino physics
  - The Particle Data Group provides an indispensable service as the repository and evaluator of results in high energy physics
  - New ideas in instrumentation can form the technical basis for ILC detectors

Present and Future Program

Present Program

- CDF is studying top cross section and mass
- Measurements of CKM parameters & B_s mixing at BaBar & CDF
- New SNe found in intermediate redshift surveys
- Supernova Factory entering operation
- First observation of Geo neutrinos in KamLAND; 4 π arm completed
- APEX-SZ nearing first light

Future Program – Centerpieces

- ATLAS pixel final assembly underway
- Berkeley role as lead of west coast ATLAS analysis center being developed
- Substantial progress on SNAP/JDEM sensor R&D

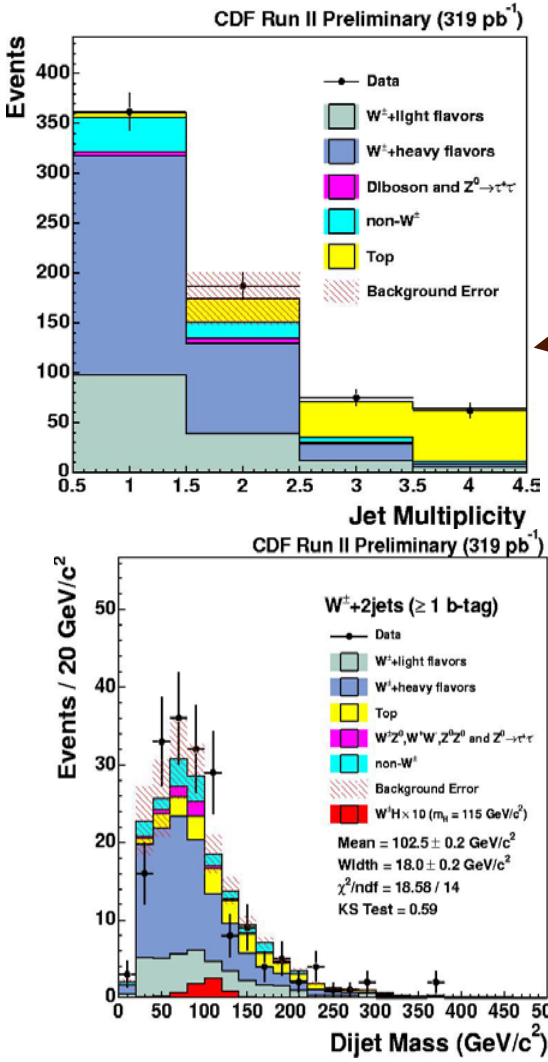
Future Program – In Development

- Instrumentation R&D, detector concept development, and Physics studies for ILC
- R&D towards a new reactor experiment at Daya Bay

Present Program

LBNL Role in CDF Physics Program

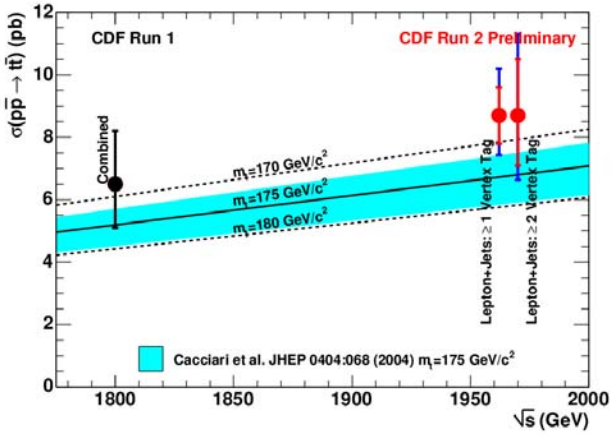
Electroweak + Top Physics



Top cross section

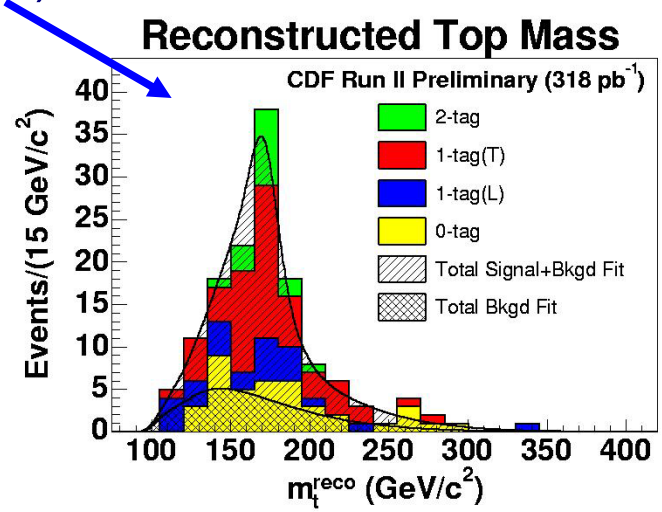
H. Bachacou (PHD thesis)

Top signal in l + 3 jets



Top Mass measurement

E. Brubaker (PHD thesis) with others



Higgs Search

$p\bar{p} \to W\,H$

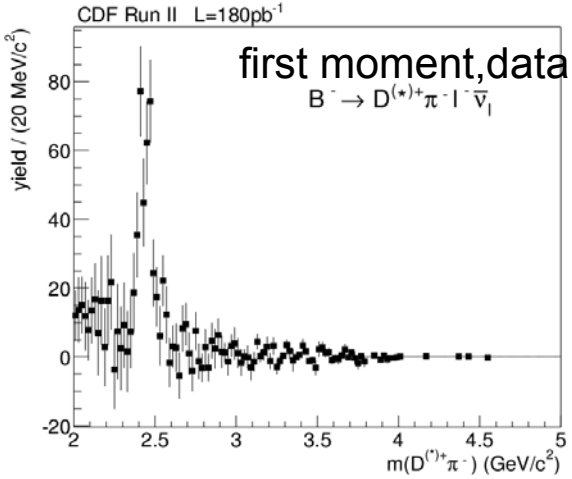
with $H \to b\bar{b}$

limit on σ

M_{top} = 172.5 ±3.9 GeV

LBNL B Physics Program

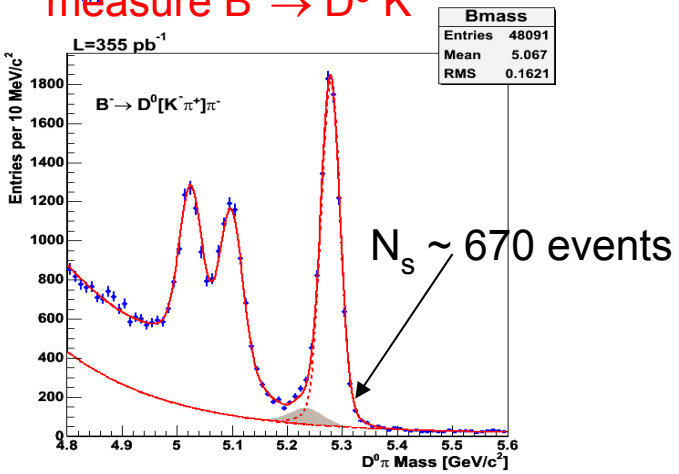
V_{cb} Hadron Moments

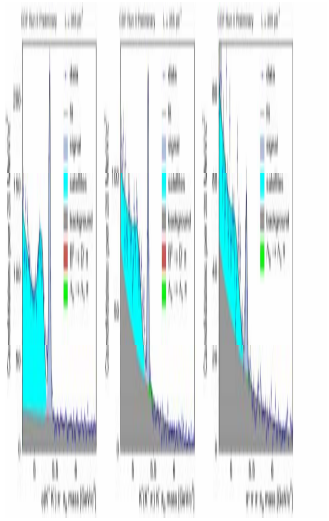


Measuring CKM parameters

Prospects for angle γ

measure $B^- \to D^o K^-$





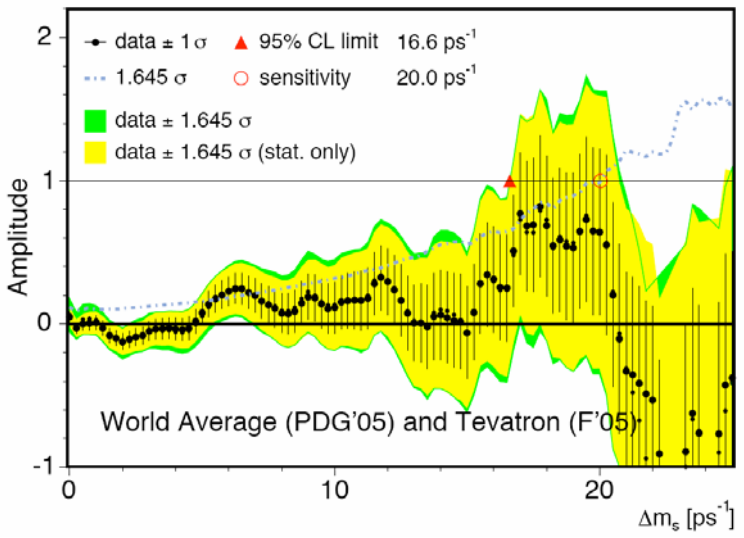
CDF Fall B_s Mixing

Limit : 7.9 ->8.6 ps^{-1}

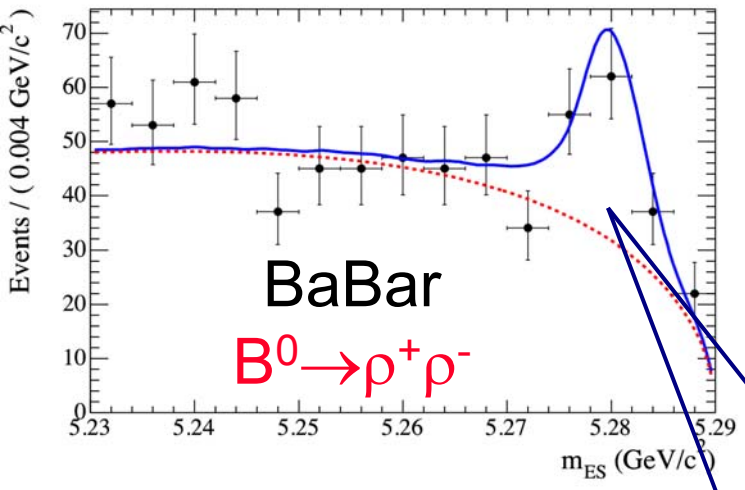
Sensi.: 8.4 ->13.0 ps^{-1}

$B_s \to D_s\pi$

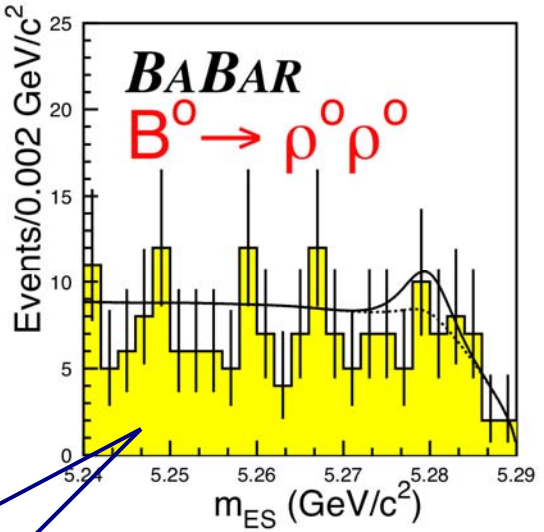
$D_s \to \phi\pi$

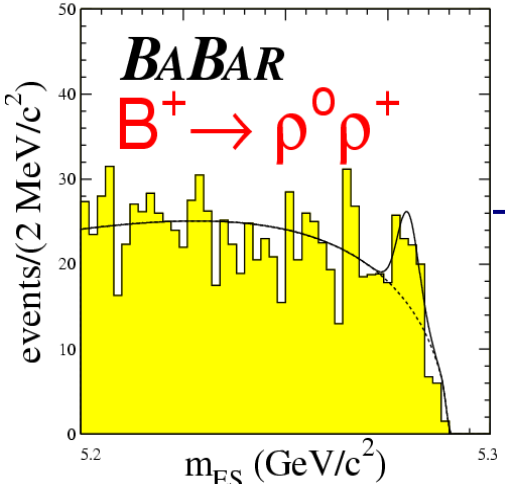


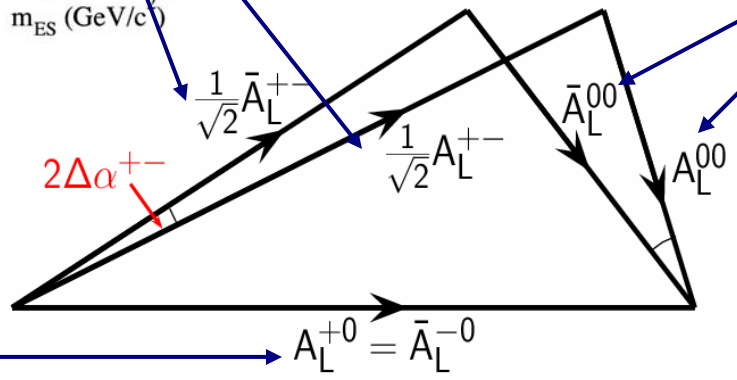
VV pioneers: extracting Δα from B→ρ ρ
(Gritsan, Groysman, Mir)



PRL 94, 131801 (2005)







BF(B→ρ^{0}ρ^0) < 1.1X10^{-6}

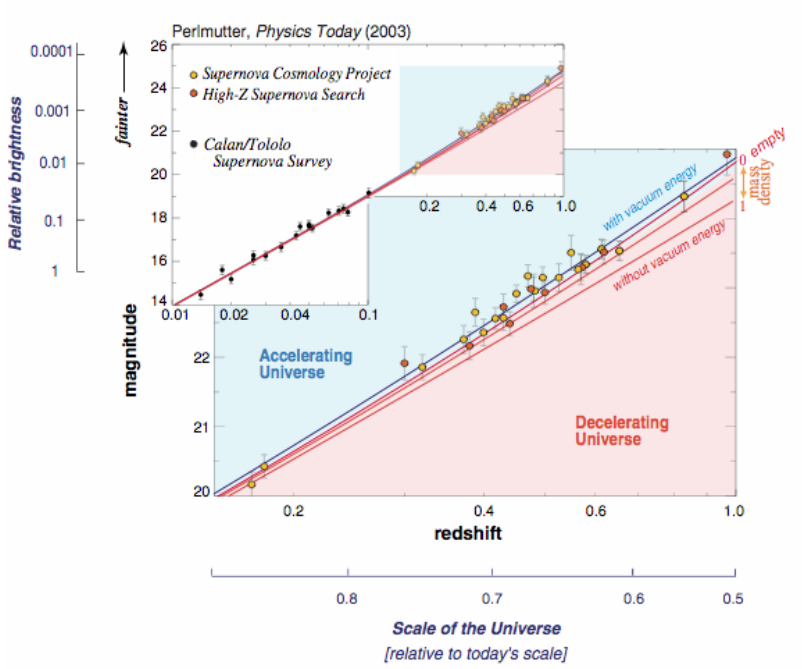
BF(B→ρ$^+$ρ$^-$) ~ 30X10^{-6}

$\alpha_{\rho\rho}$ = 96° ± 10(stat) ± 4(syst.) ± 11(Δα)

$\alpha_{\pi\pi}$ = ± 35(Δα)

Pioneers in Supernova Cosmology

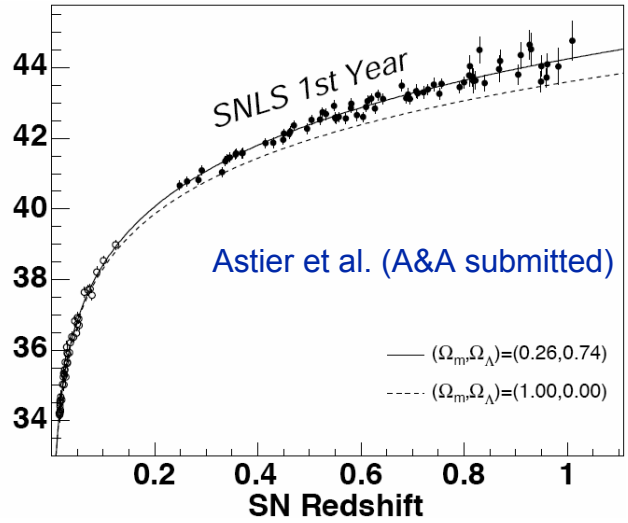
Supernova Cosmology Project



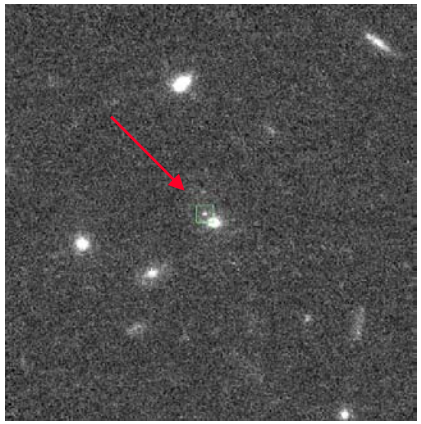
LBNL discovery of the acceleration of the universe established the new field of supernova cosmology and, more generally, dark energy studies

Current Efforts

SNLS survey at intermediate redshifts



Major HST SN search in high redshift clusters ($z \geq 1$)

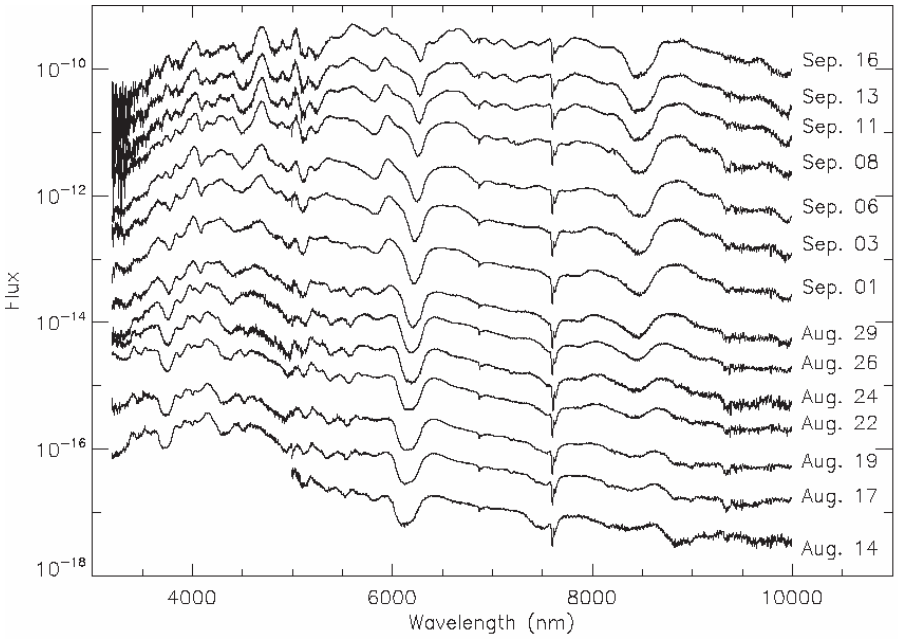


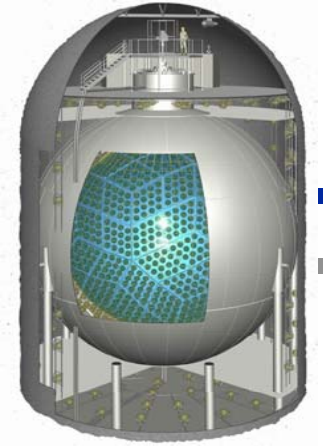
SN Ia discovered in Aug with HST/ACS in galaxy cluster at z=1.02

SuperNova Factory

Remotely operated spectrograph (SNIFS) on the University of Hawaii 2.2m telescope (w/ Keck and Subaru in background). To date it has netted 65 SNfactory SNe plus as many community SNe.

SNIFS spectral time series of the Type Ia supernova SN 2004dt (with arbitrary offset; no absolute calibration)

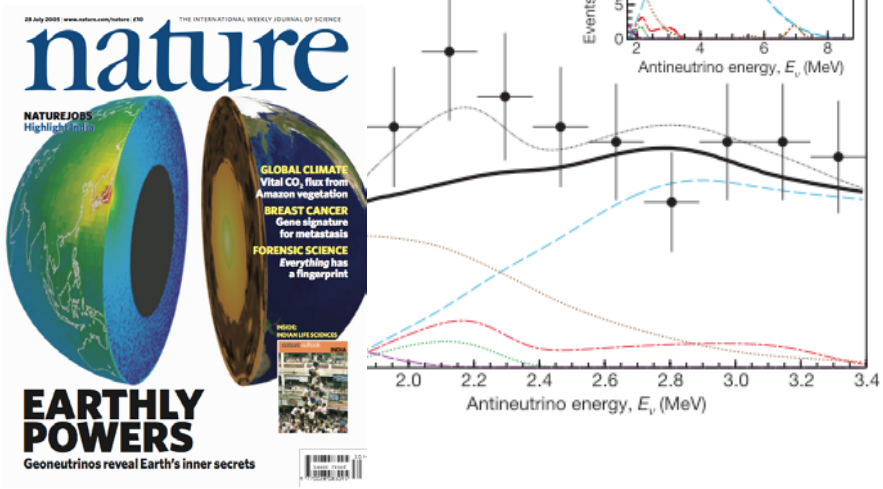




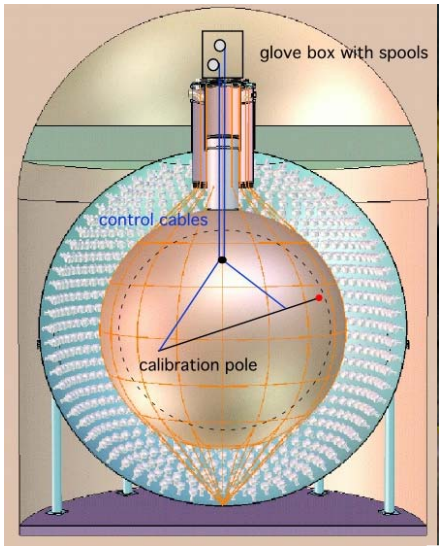
KamLAND in 2005

Continuing Discoveries

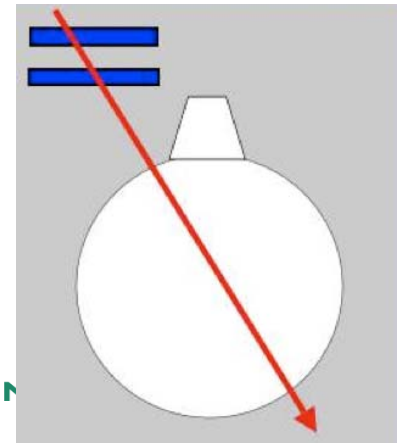
2003 Observation of $\overline{\nu}_e$ disappearance
2004 Evidence for $\overline{\nu}_e$ oscillation
2005 First Observation of Geoneutrinos



Completed Construction & Testing of 4π Calibration System



Muon Tracker Construction



CMB and Cosmology

- Integrated program combines effort at LBNL + UCB
- Strong program in theory, data analysis, algorithms
  - — MAXIPOL, Planck
  - — Collaboration with NERSC
- New instrumentation enables new experiments
  - — APEX-SZ, South Pole Telescope
    - Galaxy Cluster Search - probe Dark Energy
  - — POLARBEAR design ripe for construction
    - CMB Polarization - probe Energy Scale of Inflation
- LBNL leads readout development
- Significant funding through campus for joint program

Atacama Pathfinder Experiment (APEX-SZ)

- **16,500 feet in Chilean Andes.**
- **12m on-axis ALMA prototype**

Berkeley SZ Receiver:

- **330 Bolometer array**
- **Discover 4000 Clusters/2yrs**
  - **Mass limit > 4×10^{14} M_0**
- **First Light *Spring 2006***
- **LBNL responsible for readout**

UC Berkeley/LBNL, MPI-Bonn/Munich, Cardiff

Galaxy Cluster Search - probe Dark Energy

Future:

- **South Pole Telescope readout**
- **POLARBEAR (B mode polarization)**

Theory Group:increasing focus on LHC

Hall *et al.* – "improved naturalness" with nonstandard electroweak sectors implies dramatic signals @LHC:

- Mirror World related to SM quanta by discrete symmetry

OR

- Two Higgs doublet model with strongly coupled heavy Higgs

Nomura *et al.* – reconciling MSSM with LEP lower limit in m_H implies σ(LSP - Nucleon) > 10^{-44} cm^2

→ ensures observable LSP - dark matter signal @LHC

Bauer & Schwartz *in progress* – apply B-physics tool,

SCET = *Soft Collinear Effective Theory,*

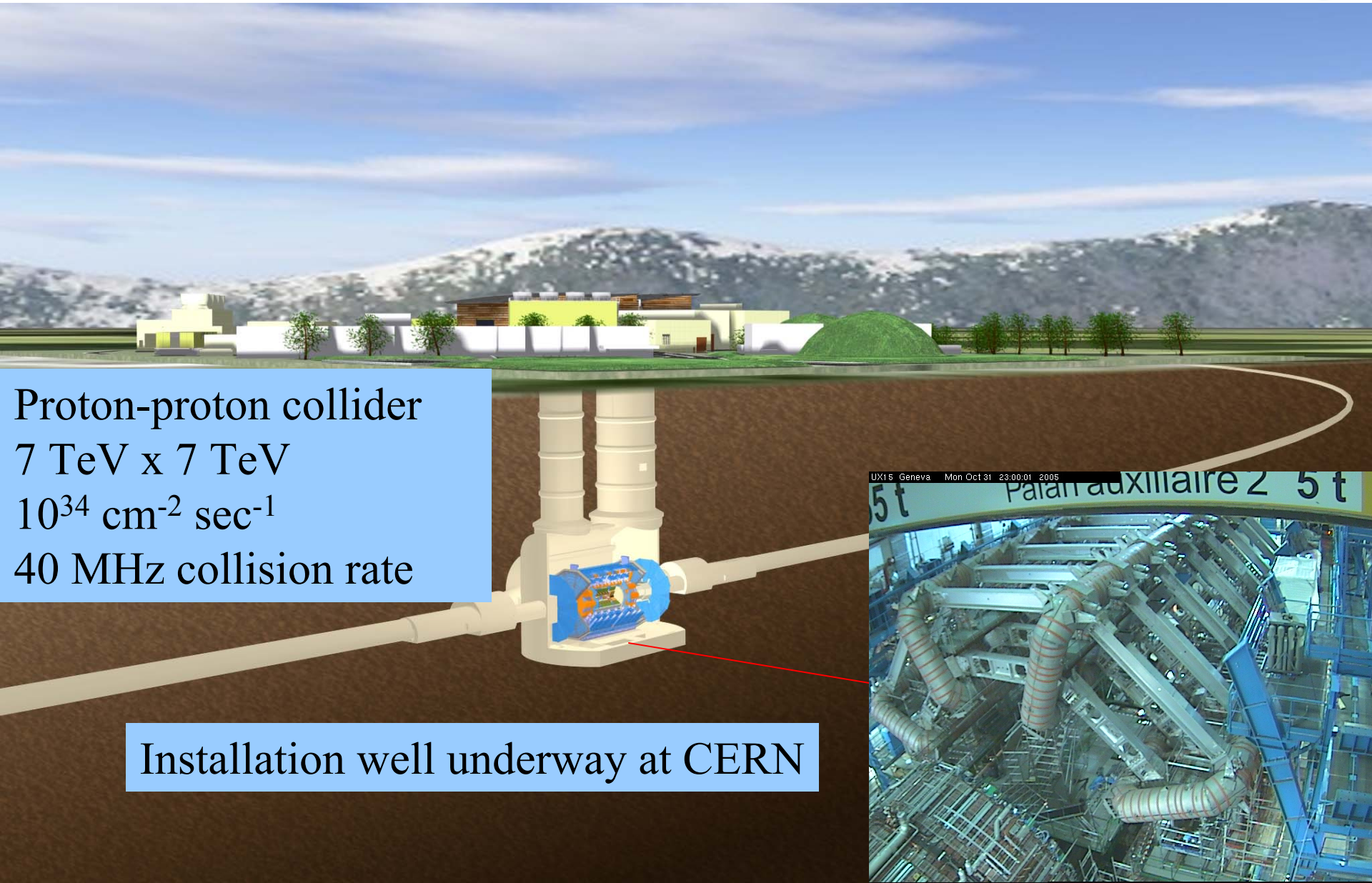
to jet physics @LHC.

Long Term Goal: multi-loop event generator for LHC

Future Program:

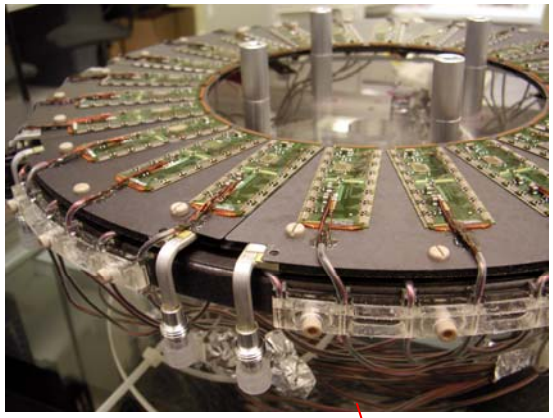
The Centerpieces

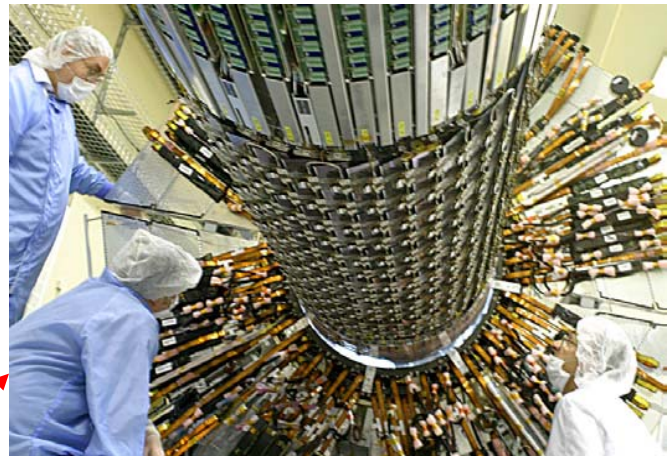
ATLAS at the Large Hadron Collider

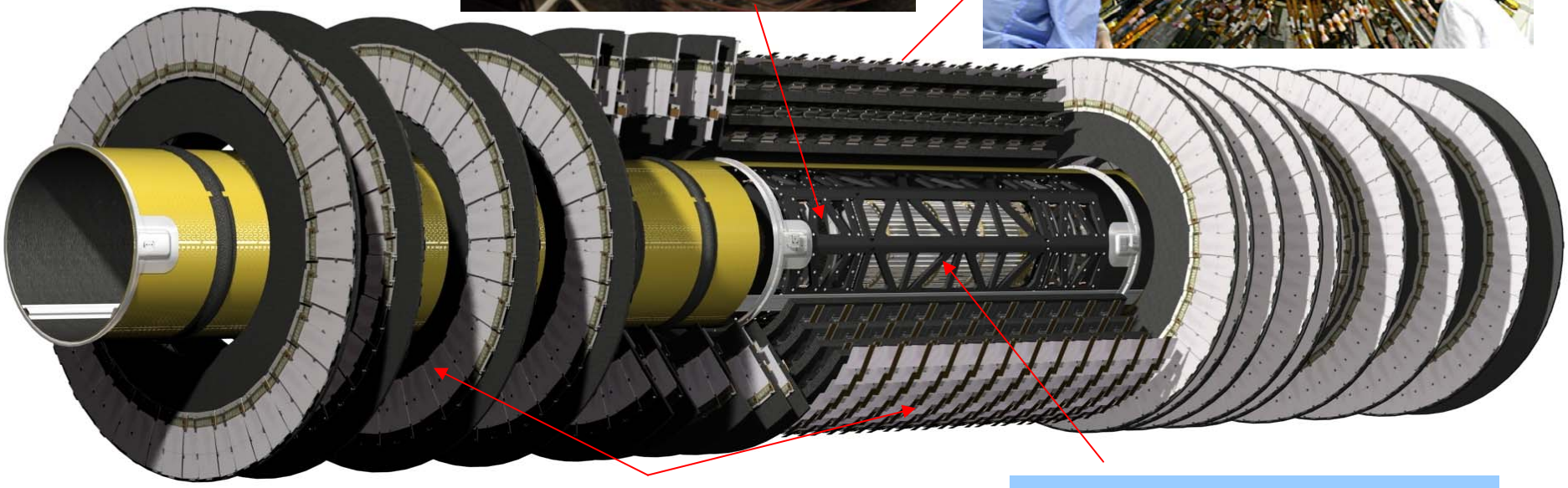


ATLAS Silicon Tracking Detector

Final assembly underway





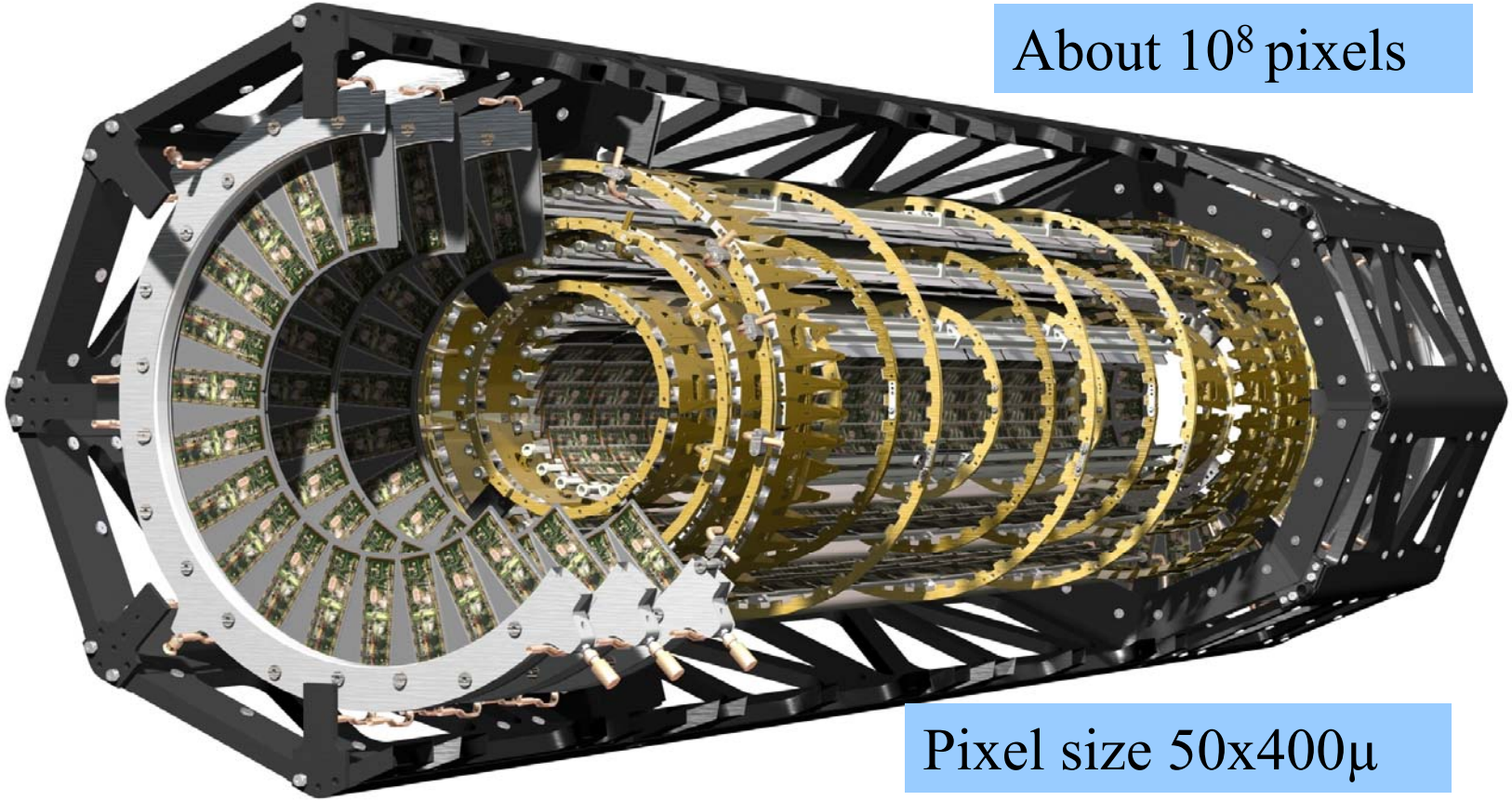


Silicon strip detector

Silicon pixel detector

Silicon Pixel Detector

- **Completion of work at LBNL by summer 2006**
- **K. Einsweiler(Pixel Project Leader) and others resident at CERN**



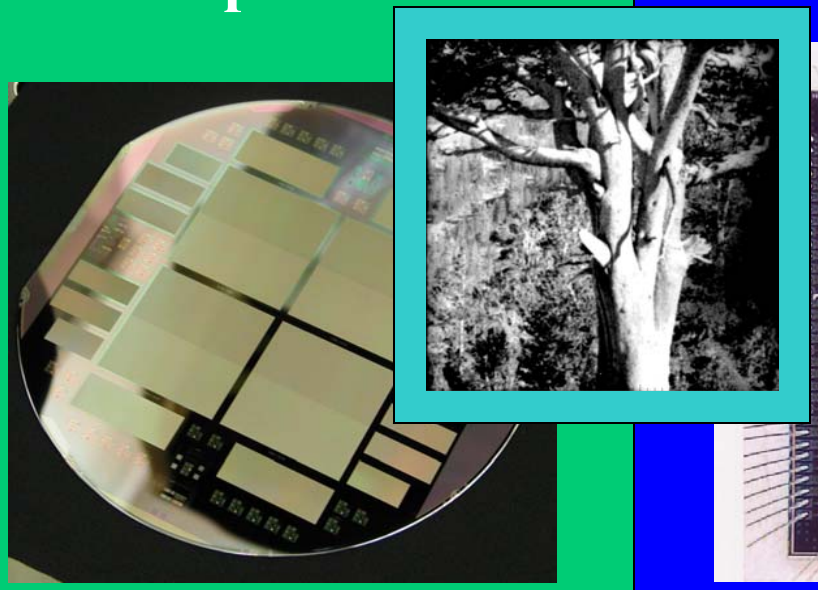
LBNL Leadership in ATLAS Physics,Software, Simulation

- Continued leadership of ATHENA framework software.
- D. Quarrie from LBNL re-elected as Software Coordinator for ATLAS and is resident at CERN
- I. Hinchliffe continues his leadership role in Physics Coordination for ATLAS, notably in data challenges leading to the most recent ATLAS Physics Workshop this past summer in Rome.
- Recent substantial increase in LBNL work on tracking software, coordinated by M. Shapiro.
- LBNL(along with ANL and BNL) selected as Analysis Support Center for US ATLAS.

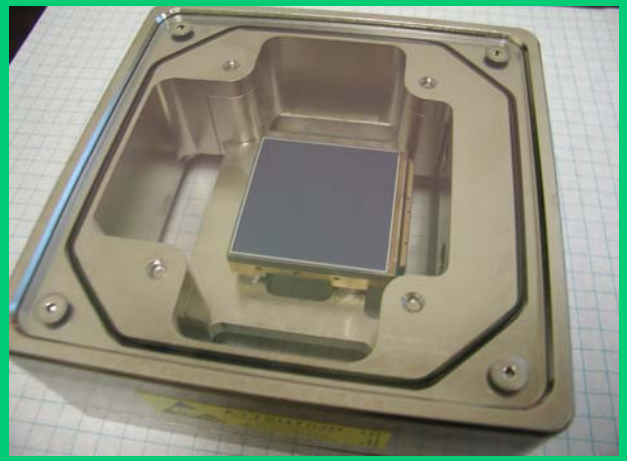
Joint Dark Energy Mission and SNAP

- High-level of SNAP R&D funding began in FY04
- Very substantial progress on R&D
- Expecting reduced level of funding through this fiscal year, FY06 (-7%).
- DOE continues to be very enthusiastic and supportive of JDEM and continues to push on NASA to establish a mission
- We are responding to NASA call for proposals for JDEM advanced mission concept studies due in March, 2006.
- SNAP Collaboration continues to grow
- Next SNAP collaboration meeting at FNAL in four weeks

Optical

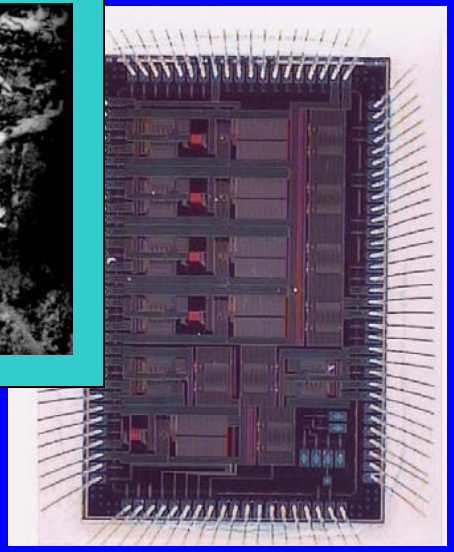


Current wafer with four SNAP CCDs – 3.5kx3.5k, 10.5 μm pixels.

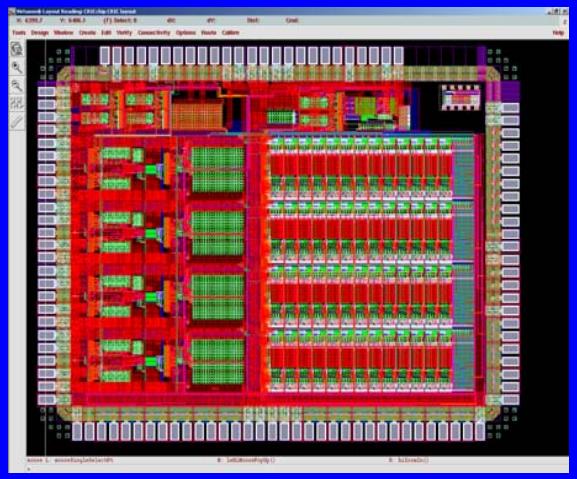


Rockwell 2k x 2k HyVisi

CCD electronics



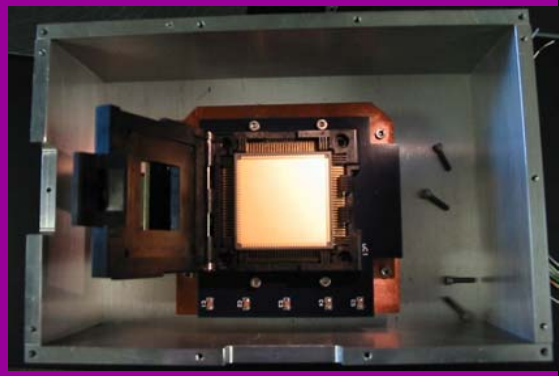
CRIC-I: Four channel dual integration correlated double sampler, operated at 140K.



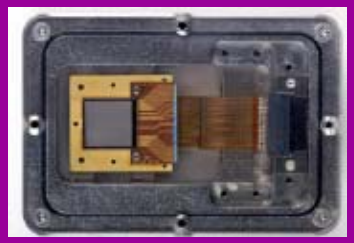
CRIC-II: with 13-b ADC

IR

Rockwell 2k x 2k, 1.7 um MCT.



Raytheon 1k x 1k, 1.7 um MCT



InGaAs 1k x 1k, 1.6 um looks like this.

Future Program:

In Development

ILC Project

Detector R&D:

- Monolithic Pixel Sensors (LDRD)
- TPC Digital VLSI Readout
- nanoBPM: high resolution beam position monitors (LCRD)

Detector Concepts:

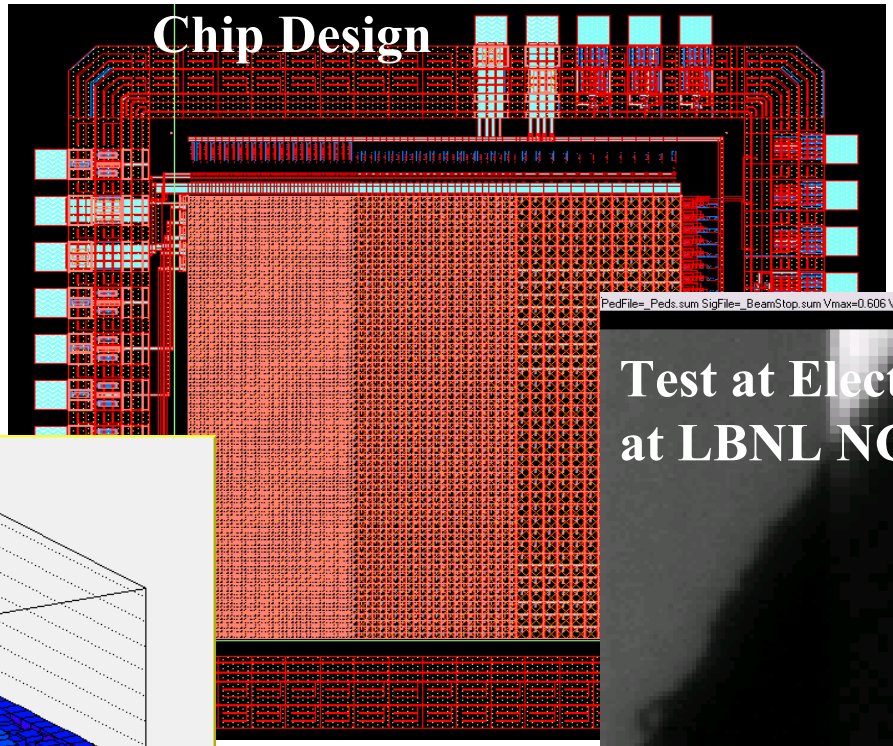
Leadership in LDC and GLD International detector concept studies

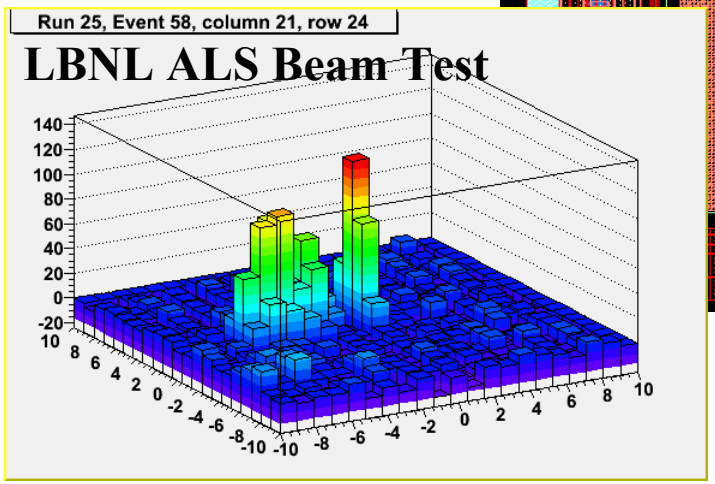
Physics studies:

- Definition of performance requirements and detector benchmarking
- Connection of ILC Physics and Cosmology (White paper on ILC and Cosmo)
- Study of interplay and complementarity with LHC physics program

LDRD Program on Monolithic Si Pixel Sensors for ILC

Development, Characterisation and Test of new Pixel Detectors with 10 μm pixels, O(1 μm) single point resolution, on-chip data reduction and fast readout (collaborative effort of Physics, Engineering, Nuclear Sciences)



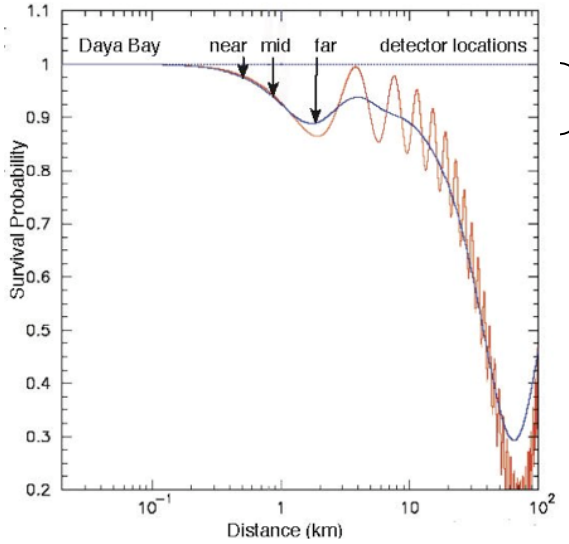


Measurement of θ_{13} with Reactor Neutrinos

Precision Measurement of U_{e3}

Neutrinos

$$U_{MNSP} \sim \begin{pmatrix} 0.8 & 0.5 & U_{e3} \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix}$$



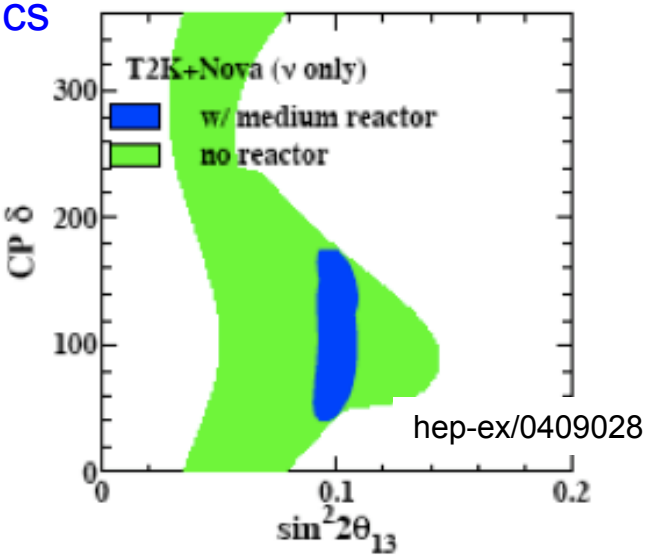
} θ_{13}

R&D Towards a New Reactor Experiment

- detector design
- cost estimates
- rock property testing
- PMT testing
- acrylic and scintillator testing
- Monte Carlo simulation

Daya Bay

Important Input to Precision Oscillation Physics



hep-ex/0409028

Community Service, Education & Outreach

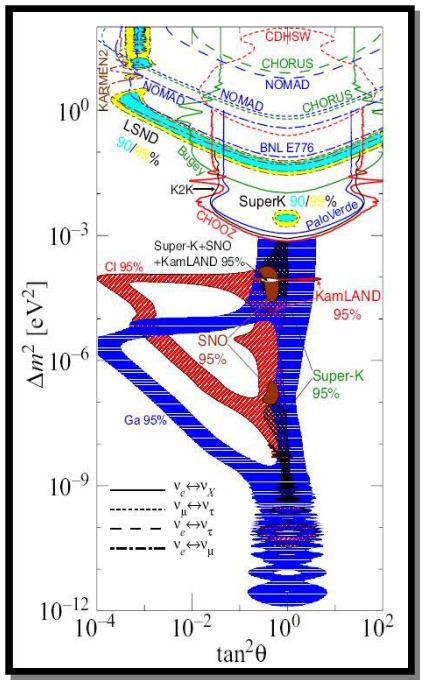
Service to the Community

Barnett	Vice-Chair, APS Calif. Sec.; VP AAPT No. Calif. Sec.; Chair, ATLAS Outreach
Murayama	FNAL PAC; DPF Executive Committee
Roe	NUSAG; FNAL PAC; URA visiting committee; RSVP scientific assessment committee; DESY Scientific Council; Vice Chair, DPF
Cahn	HEPAP; Dark Energy Task Force; Chair, RSVP scientific assessment committee
Siegrist	MUCOG; LHC oversight
Perlmutter	HEPAP; JDEM Science Definition Team
Carithers	Chair, DPF
Levi	JDEM Science Definition Team
Linder	JDEM Science Definition Team

Particle Data Group 50th Anniversary

- Review of Particle Physics
- Education/Outreach Programs

Leading a Collaboration of 156 authors from 17 countries (90 institutions) + 700 contributors.



RPP: 500 new papers, 1700 new measurements, 119 reviews.
28,000 Booklets, 13,000 RPP books, website: 5-10 million hits/yr.

According to SLAC Library, RPP is the all-time top cited article in HEP with 21,500 citations (2nd is Weinberg's SM paper with 5424).

★ Improved coverage though vital PDG workshops: Neutrino, CKM, Extra-dimensions, Statistics,…

★ Growing coverage of Astrophysics and Cosmology

Education and Outreach

Involving Students, Teachers & the Public

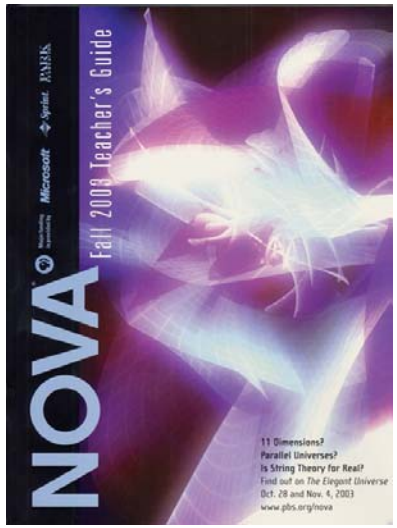
QuarkNet sites

QuarkNet – Co-Founder and Co-PI

Centers at 54 universities, 11 different HEP experiments, 500 high schools in 37 states. Impacts on 60,000 students/yr.

Changing teachers and teaching by making them part of of research collaborations.

Collaboration with NOVA on "Brian Greene's Elegant Universe"

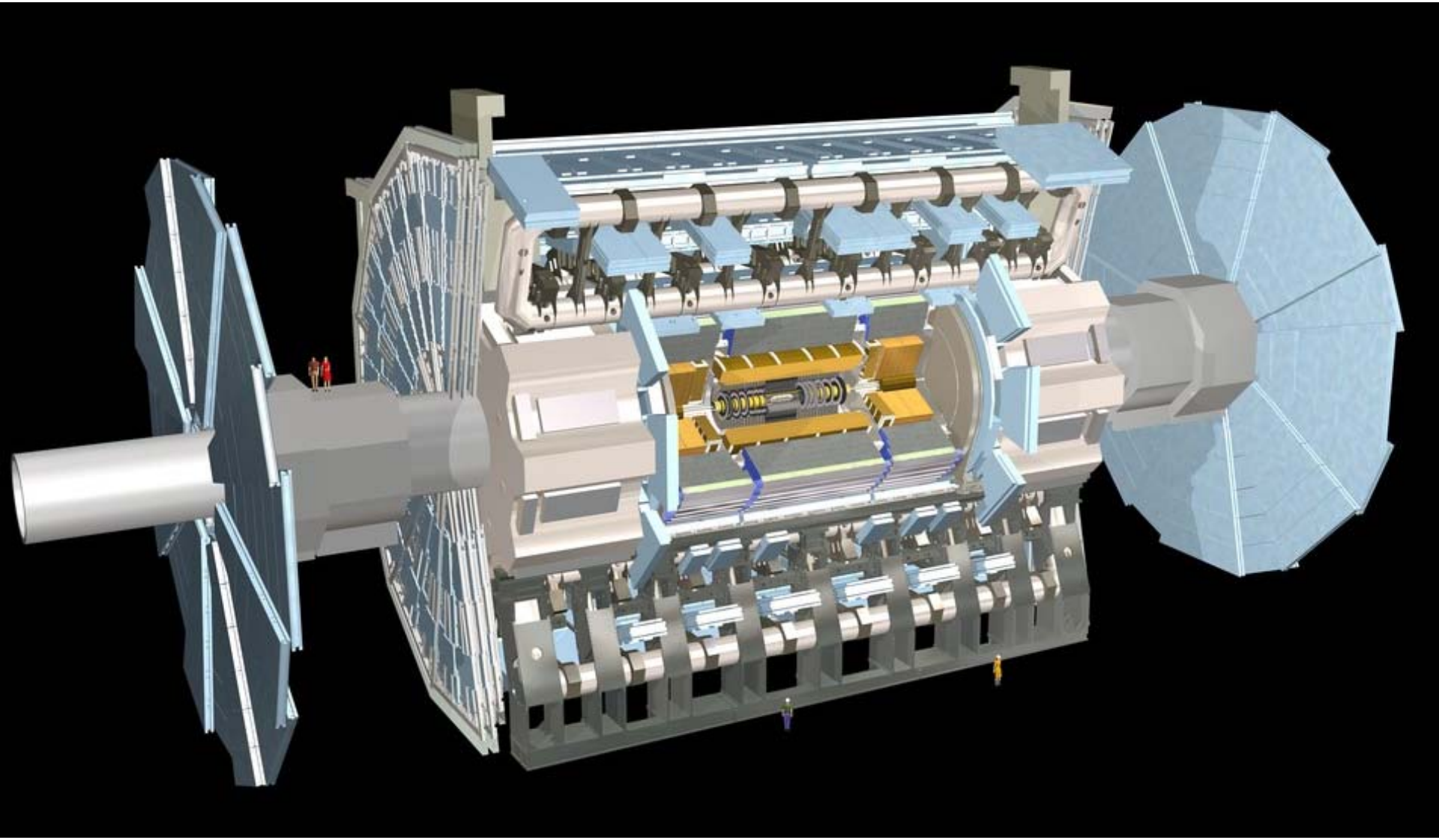


The Particle Adventure

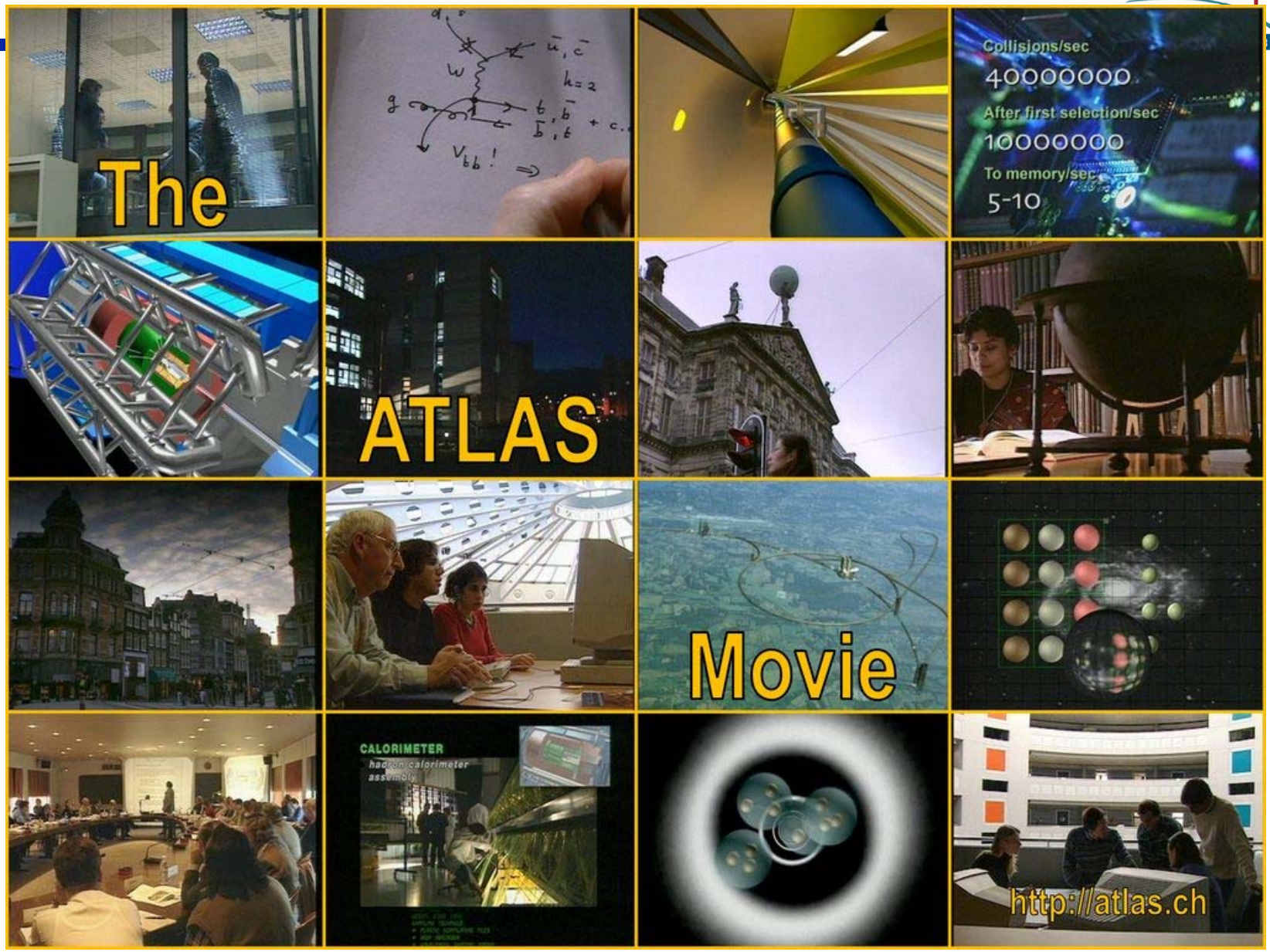
Languages: Spanish, French, Polish, Finnish, Chinese, Italian, Portuguese, Slovak, Greek, German, Norwegian, Dutch.

Featured by: Scientific American, Discovery Channel, USA Today, Education World, DOE's KidzZone,

ATLAS Animation



ATLAS Reaches Out



Funding and Division-wide Issues

Budgetary Outlook

- **FY04-FY06 budget decrease could not be absorbed without severe damage to the program**
- **We have reduced the size of our workforce via reduction in force during FY05**
  - **~20% drop in permanent scientific staff**
  - **~25% drop in administrative support costs**
- **Continued staff reductions in CDF and BaBar efforts**
- **We are reducing research efforts across the division to match funding**

Concerns and Risks

Our program is well aligned with the priorities of the field BUT

- **Delays in JDEM/SNAP R&D put at risk technical readiness for project start**
- **Because ATLAS is under-funded, we are reaching out to the University community to seek new collaborators**
- **Because our supernova cosmology program is under stress, we are rethinking our long-term plans**
- **Because we cannot further cut ATLAS or SN Cosmology, we have ramped down strong analysis efforts in BaBar and CDF**

Budget Information ($K)

	FY04 Actual	FY05 Allocation	FY06 President's
LBNL Physics Research	21419	19165	18293
ATLAS Project	3694	2434	2020
JDEM/SNAP R&D	2498	2950	2900
Total Funding	27611	24549	23213

LDRD Support for Physics

Title	PI	2002	2003	2004	2005	2006
						(10/05)
Foundations for a SuperNova/ Acceleration Probe (SNAP)	Levi/Perlmut	1,199,700	—	—	—	—
Modeling of High Energy Physics Detectors	Hinchliffe	94,600	99,800	—	—	—
POLARBEAR: An Experiment to Measure Polarization Anisotropy in the CMB	Lee	101,400	100,100	—	—	—
Future Experiments in Neutrino Physics	Freedman	x	47,000	64,000	—	—
Designing a Novel Reactor Neutrino Oscillation Experiment for Measuring the Unknown Mixing Angle Theta-13	Heeger et al.	x	x	263,300	300,000	300,000
Silicon Detectors for a Linear Collider	Battaglia	x	x	x	180,000	220,000
New Directions for Theoretical Physics at the Tev-Scale	Murayama	x	x	x	250,000	250,000

Areas for Advice

- Advise Steve Chu on the quality and impact of our work
- Advise us how to improve making our science case to the community
  - — we are seeking support from our collaborations & building broader user support
  - — ongoing physics at LBNL squeezed dramatically…
- How do we make the case to the lab for further investment in the Division in the post-SNAP LDRD era?
  - — Neutrinos
  - — Astrophysics development, theory and experiment
  - — New instrumentation for future experiments and other fields
- How do we make a better enterprise with the support we have now?
- What opportunities are we missing? What are we “not seeing”?

Summary

- **Present program is producing great physics**
- **Future program is very exciting, technical progress is excellent**
- **New ideas are very attractive**

LBNL is a center of excellence that serves the HEP community well

Prospects

We look forward to great physics!

- ***CP violation***
- ***Higgs***
- ***SUSY***
- ***Dark energy***
- ***Extra dimensions and even more***